

**Shell Canada Limited
Sour Gas Pipeline Failure
Licence No. 23800, Line No. 61
November 19, 2007**

ERCB Investigation Report

October 7, 2008

Report prepared by Brian Temple (Incident Investigator), Brad Olive (Field Surveillance), Dave Grzyb (Operations), Murray Barber (Field Surveillance), Al Duben (Field Surveillance), Jessica Schlager (Emergency Planning and Assessment), Bruce Greenfield (Environment), Kristofer Siriunas (Environment)

ENERGY RESOURCES CONSERVATION BOARD

ERCB Investigation Report: Shell Canada Limited, Sour Gas Pipeline Failure

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640 – 5 Avenue SW
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T2P 3G4

Telephone: 403-297-8311
Fax: 403-297-7040
E-mail: Publications@ercb.ca
Web site: www.ercb.ca

Contents

1	Incident Overview	1
1.1	Pipeline History	4
2	Significant Findings	5
2.1	Shell Canada Ltd. Investigation	5
2.2	ERCB's Investigation	6
3	Actions Taken to Prevent Recurrence	7
3.1	By Shell Canada Ltd.	7
3.2	By the ERCB	9
4	ERCB Directed Actions	9
5	ERCB Follow-up	9
	Appendix A: Surface Location of HDPE Pipelines in Waterton Area	10

1 Incident Overview

At about 8:56 a.m. on Monday, November 19, 2007, the Shell Canada Limited (Shell) Waterton Complex Control Room received alarms through its Supervisory Control and Data Acquisition (SCADA) system indicating low pressure in a 6-inch (152 millimetre [mm]) sour gas pipeline. The SCADA system also initiated closure of the emergency shutdown (ESD) valves at about 8:58 a.m., as it was programmed to do in response to a possible release situation.

The control room operator contacted field operations to investigate the cause of the alarms, and at about the same time the control room received two odour complaints from area residents. The field operators reported hydrogen sulphide (H_2S) in the vicinity of the release site at a location in the Screwdriver Creek pipeline segment Legal Subdivision (LSD) 10-7-6-2W5M to 6-17-6-2W5M about 20 kilometres (km) west of Pincher Creek near the Hamlet of Beaver Mines.

Between 9:00 and 9:30 a.m., Shell's Emergency Response Plan (ERP) was activated and the Local Emergency Operations Centre (LEOC) and Incident Command were established. Immediate action was then taken to protect residents in the vicinity of the release site, who were either advised to shelter in place or escorted from the area. A seismic crew and other contractors working in the vicinity of the release site were also advised to leave the area.

Actions were also initiated to secure the release site, deploy reconnaissance teams to the area of the release, establish roadblocks, deploy mobile and handheld air monitoring units (AMUs), and contact first responders and regulatory authorities.

The Energy Resources Conservation Board (ERCB) Midnapore Field Centre (MPFC) was notified of the incident at about 9:20 a.m. by Shell. In consultation with Shell, the MPFC classified the incident as a Level-1 emergency using the ERCB's Assessment Matrix for Classifying Incidents. Field inspectors from the MPFC were dispatched to the site at about 9:45 a.m.

Between 9:30 and 10:00 a.m., Shell issued a precautionary evacuation message to area residents. Priority was given to those members of the public requiring early notification, including residents within and outside the emergency planning zone (EPZ).

Readings between 9 parts per million (ppm) and 31 ppm H_2S were recorded in the EPZ area northeast of the release site between 9:00 and 10:00 a.m. by Shell staff using handheld H_2S monitors.

The MPFC notified the ERCB Emergency Response Group (ERG) at approximately 10:15 a.m. The ERCB AMU, operating in the Vulcan area, was dispatched to the incident.

Between 10:00 and 10:30 a.m., subsequent callouts to the public were undertaken based on local weather data and handheld H_2S monitoring data and resident proximity to the release. A Shell field operator was transported by helicopter to locate the specific release site (14-8-6-2W5M). This information was communicated to the Shell IC and was used to isolate and secure the release site by Shell staff. The release site was confirmed to be the Screwdriver Creek Pipeline, Licence No. 23800, Line No. 61, which was a 6-inch steel pipeline containing a high density polyethylene (HDPE) corrosion barrier liner.

Between 10:00 and 10:30 a.m., changing wind conditions were observed during the response to the incident. Shell expanded its public callout as a result of the change in wind conditions, and two residents near the release site who were previously sheltering in place were evacuated. Other residents in the Beaver Mines area were advised to shelter in place and Shell's communication with residents in the area continued. Readings between 1 and 5 ppm H₂S were recorded in the EPZ area northeast of the release site.

A reading of 4 ppm H₂S was recorded by Shell staff using handheld H₂S monitors outside of the EPZ east of the Hamlet of Beaver Mines site at 10:05 a.m.

At 10:15 a.m., Shell contacted the MPFC with updated information and, in consultation with the ERCB, the incident was escalated and classified as a Level-2 emergency using the ERCB's Assessment Matrix for Classifying Incidents.

Over the next few hours, Shell

- 1) established a reception centre at the Pincher Creek Fire Hall,
- 2) continued callouts to the public based on changing wind directions,
- 3) continued helicopter reconnaissance to further survey the area in the vicinity of the release site,
- 4) dispatched personnel to one residence to address the specific concerns of that resident,
- 5) established additional roadblocks, and
- 6) provided updates to government agencies and other stakeholders.

At 11:45 a.m., the ERCB AMU arrived in the area and began monitoring in the Hamlet of Beaver Mines and surrounding area. Readings of 2 parts per billion (ppb) H₂S within the hamlet and 11 ppb H₂S outside of the EPZ south of the Hamlet of Beaver Mines were recorded.

At 12:45 p.m., MPFC inspectors arrived on site (Shell's LEOC) and received an update of the incident by Shell. The update included information on residents evacuated, odour complaints, and pipeline shut-in time.

At 1:30 p.m., the MPFC inspectors and Shell visited the release site and noted the area impacted by the release. Readings of 10 ppm H₂S were recorded by the ERCB on handheld H₂S monitors.

At approximately 2:00 p.m., the incident was reviewed by Shell and the ERCB and the incident was called down to a Level-1 emergency. Roadblocks were removed from all locations except at the Seven Gates Road access and residents were allowed to return.

At approximately 3:00 p.m., the ERCB AMU conducted monitoring at the release site. The AMU was positioned immediately downwind in the field adjacent to the release site and recorded a peak reading of 13 ppb H₂S. No detectable readings were recorded on the Seven Gates Road. With this information, Shell, in consultation with the ERCB, made the decision to stand down the emergency. Stakeholders were contacted and advised of the emergency stand-down. The AMU contracted by Shell and a security team were to remain in the area overnight. At 3:30 p.m., ERCB staff participated in an incident debriefing by Shell.

On November 20, 2007, Shell voluntarily shut down production through all lined pipelines in the Waterton field as a precautionary measure pending evaluation of this pipeline failure.

Between November 20 and December 1, 2007, Shell undertook the following by e-mail, letter, telephone, and/or in person:

- 1) followed up with stakeholders who were contacted by telephone as part of the callout on November 19, 2007,
- 2) discussed and provided stakeholders with an update on the incident,
- 3) sent a follow-up letter to all the residents within the EPZ from the manager of the Waterton Complex explaining the incident,
- 4) established an information table at the Beaver Mines General Store, manned by Shell's public consultation advisor for the Waterton area, to provide an informal opportunity for the public to ask questions about the incident and Shell's operations in the area,
- 5) attended the Buffalo Resources Community Open House at the Twin Butte Community Hall to answer questions from residents in the south end of the Waterton field, and
- 6) met with local ranchers to discuss their concerns about the potential impact of the incident on their cattle and Shell's plans in that regard.

On November 21, 2007, Shell voluntarily shut down wells and pipelines in the Castle River, Burmis, and Sorge areas as a precaution. On November 22, 2007, a small excavation of the pipeline failure point began to allow for an examination of the pipeline. The pipeline failure site was exposed and various pipeline coverings removed.

On November 23, 2007, Acuren Materials Engineering & Testing (Acuren) was contracted by Shell to provide third-party failure analysis.

Between November 26 and 30, 2007, a temporary pipeline repair sleeve was installed on the failed pipeline segment and the pipeline was pressure tested, pigged to remove any sour liquids, and purged with sweet gas to flare. Stripping of top soil began in preparation of exposing the pipeline section and contaminated soil was removed to the Shell Waterton Class II Oilfield Waste Landfill.

The MPFC received 13 public complaints as a result of this incident. The MPFC addressed each complaint immediately and then followed up with personal site visits to those that were home on November 27 and 28. The MPFC team leader and ERCB Community and Aboriginal Relations assistant team leader visited each complainant that was home during the two-day period. An information package was sent to those residents who were not home.

On Dec 1, 2007, the ERCB was on site to witness the separation and sealing of the pipeline flanges and the removal of a 34 meter (m) section of pipeline, using cold-cut procedures. The cut end of the pipeline was capped and sealed. The section of pipeline removed was cut into two pieces and all ends were capped, sealed, and transported to a secure location to minimize potential odour issues. Mobile AMUs, which operated throughout the incident, were released from service on December 1, 2007, following the pipe removal and isolation of the pipeline.

On December 2, 2007, Acuren began cutting the pipe into sections suitable for transportation, using appropriate equipment. The sections containing the pipe failure were transported to Acuren's facility in Calgary for failure analysis and material testing. Shell installed culverts at the cold-cut location and the flanges and back filled the excavation site.

Traffic control and site security were maintained throughout the incident with site security removed on December 2, 2007, after pipe removal and isolation of the pipeline.

On December 4, 2007, Shell began installing a semipermanent fence around the site for winter security. On December 7, 2007, remediation activities and fencing at the release site were completed by Hazco Environmental Services Ltd. (Hazco), with only a decision about topsoil replacement outstanding. Traffic control was discontinued after completion of the remediation activities by Hazco.

Shell contracted WorleyParsons Komex to develop the environmental site assessment and reclamation plan.

Between December 10 and 21, 2007, Shell met with the Pincher Creek Town Council and the Municipal District (MD) of Pincher Creek and an update letter was sent to residents within the EPZ.

On December 27, 2007, two complaints were received by the ERCB (FIS No. 20073108 and No. 20073110) about odours at the release site. Upon investigation, the source was determined to be the pipeline cap that had been installed on the failed pipe body to seal the cutout. This cap had an inadequate seal. On December 28, the cap was replaced and the seal welded to the pipe.

On February 15, 2008, Shell was advised by the ERCB that the lined pipelines that Shell voluntarily removed from service following this event will have to remain out of service until the ERCB agrees that service of those pipelines may be resumed. The pipelines in question are indicated in Appendix A.

Communication between Shell and the ERCB has been maintained by daily updates of Shell's activities in the area and work done on the pipelines.

The incident was classified as a Level-2 emergency by the ERCB and Shell. The release occurred in a populated rural area and the incident received media attention. A press release was issued by the ERCB Communications Group that the incident would be investigated.

1.1 Pipeline History

The pipeline was constructed in accordance with the *Pipeline Regulation* and *CSA Z662-99: Oil and Gas Pipeline Systems*, with the Screwdriver Creek segment installed in November 2001 with an internal liner made of Rilsan (nylon) material. The Rilsan liner was replaced with an HDPE liner in December 2003 after it was found that Rilsan liners were being negatively impacted in pipelines carrying similar fluids. Shell had learned in 2002 that methanol and hydrocarbons diffused/permeated through the Rilsan and into the small annular space that exists between the tight-fitting liner and the steel pipeline. Shell had also learned that the methanol degraded the Rilsan material by leaching out plasticizers and depositing them as a residue within the annulus. Replacement of the Rilsan by HDPE was done to alleviate these potential concerns regarding liner performance.

Prior to installing the HDPE liner, the pipeline was inspected visually at the flange ends of each segment, by removal of two cutouts for laboratory inspection, and with a tethered inspection tool. Eight pipeline locations (including the subject failed portion), each about 80 m in length (the capability of the tool at that time), were inspected. The visual inspections did not identify any significant corrosion, and the electronic inspection tool did not indicate

the presence of any internal corrosion that exceeded the minimum detection limit of the electronic tool. The HDPE liner was installed and the line resumed operation in December 2003.

2 Significant Findings

2.1 Shell Canada Ltd. Investigation

The Acuren Failure Analysis Report stated that the pipeline failure (i.e., an axial split in the steel of about 300 millimetres [mm] in length with a maximum width of 60 mm at centre) was the result of tensile overload of the steel pipe in a localized area where internal corrosion had removed almost 90 per cent of the pipe wall.

In sour gas pipelines it is typical for a protective iron sulphide scale to form on the pipe walls. If intact, this scale can provide the steel with effective corrosion protection. In this case, it appears that the protective iron sulphide scale had not existed in a uniform manner, and as a result corrosion was able to occur in numerous localized areas. In those locations, a paste-like mixture of iron sulphide corrosion product suspended in an acidic liquid was found to be sandwiched in the annulus between the HDPE liner and the steel pipe. The liquid component was believed to be primarily methanol, which is used in the pipeline for hydrate control. Methanol is known to permeate through the HDPE liner and was used to flush the annular vent system of the pipeline, thus establishing its presence in the liner annulus. There was no evidence that chlorides, bacteria, or elemental sulphur played a role in the corrosion process.

Further investigation by the Shell Calgary Research Centre identified the following major factors that contributed to the failure:

- Discrete patches of nonprotective scale associated with minor corrosion that had occurred when the pipeline was operated with a Rilsan liner remained when the HDPE liner was installed. These discrete patches of nonprotective scale rendered the batch inhibitor ineffective at those locations and also prevented the formation of protective scale, thus allowing localized corrosion to occur.
- Corrodents present in the annulus from a number of sources did not allow the formation of protective scales to occur and further promoted and provided the conditions for ongoing corrosion. Methanol and water (the main corrodents), present at high concentrations and under the right conditions in the annulus, promoted corrosion.
- The nonprotective scale, together with liquid and solid debris, partially blocked the annulus vent system, creating poor annulus communication and high annulus pressure that, with the presence of the corrodents, created a more acidic and corrosive low pH environment. These conditions exacerbated the corrosion.
- There was insufficient flow/velocity in the annulus vent system to effectively sweep liquids (and solids) from the annulus. The complex flow path and low-flow conditions, especially adjacent to the bellholes, created liquid traps preventing the liquids and solids from being swept from the annulus.

Other factors that might have contributed to the failure were as follows:

- the pipeline might not have been completely pigged clean of liquids following the hydrotest prior to installation of the HDPE liner or following prior inspection tool runs, and
- formic acid, used for well stimulation, might have also permeated the liner as a vapour and further contributed to the low pH condition in the pipeline annulus.

The pipeline is equipped with ESD valves and check valves that are designed to automatically isolate sections of the pipeline and limit the release of natural gas in the event of a line failure. The valves functioned as designed during the incident, thereby limiting the extent of the release of natural gas.

The duration of the incident was estimated from pipeline pressure and flow data, which showed that flow increases and pressure drops occurred between 8:50 and 8:51 a.m., indicating the approximate start time of the incident. Flow decreased to zero between 8:59 and 9:00 a.m., and pressure decreased to 0 at about 9:10 a.m., indicating the approximate end time of the incident. Based on these approximate start and end times, the duration of the incident was estimated to be 20 minutes.

The pipeline is licensed to a maximum absolute operating pressure of 12 400 kilopascals (kPa) and a maximum H₂S concentration of 32 per cent. The pipeline was carrying natural gas containing 20.9 per cent H₂S and was operating at a pressure of 4300 kPa at the time of the incident.

The volume of lost production associated with the incident is 100 thousand cubic metres per day (10³ m³/d) from the wells at Waterton (WT) 61 (66 10³ m³/d) and WT 10-7 (34 10³ m³/d). The loss is associated with the shut-in of natural gas production from these two locations due to the line failure. In addition, Shell shut down production from the north Waterton field as a precaution. The lost production of natural gas from these sources is about 1900 10³ m³/d.

About 730 m³ of impacted soils were removed from the site and disposed of at the Shell Waterton Class II Oilfield Waste Landfill.

2.2 ERCB's Investigation

The ERCB accepts Shell's technical explanation of the nature and circumstances of the internal corrosion and acknowledges the subsequent activities being undertaken by Shell to inspect other similar pipelines for potential corrosion problems.

Pipeline pressure profile data indicated that the release started between 8:50 and 8:51 a.m. The SCADA alarms were received at 8:56 a.m. and the system initiated pipeline shutdown at 8:58 a.m., indicating that the system performed in a satisfactory manner and the subsequent actions to completely shut down the entire pipeline were initiated promptly.

All required agencies were contacted (ERCB, Pincher Creek Disaster Services, the Regional Health Authority, RCMP, Alberta Environment, Alberta Sustainable Resource Development [Public Lands and Forests], and the MD of Pincher Creek).

The contracted AMU that was dispatched to the incident arrived in a timely matter (about 6 hours), given that this unit's home base is in central Alberta (Red Deer). On arrival, it was positioned in the Town of Pincher Creek. When the AMU was finally dispatched to the

incident location, it was positioned on the lease close to the line break. The ERCB believes that data from air monitoring are needed to ensure public and worker safety and advises Shell to acquire a unit closer to the site of the incident.

The handheld monitors that were used to collect air monitoring data by Shell staff could not be verified as being accurate. Shell was unable to provide evidence to verify that recent calibrations or bump tests had been conducted. The monitors in use did not have on-board data storage capability to record data and calibrations; therefore, the data coming from these units have limited use.

The Shell ERP was found to be compliant with ERCB *Directive 071: Emergency Preparedness and Response Requirements for the Petroleum Industry*. All residents that were required to be notified (according to the ERP and resident contact list) were notified.

Shell conducted open houses and met with local ranchers following the incident. Meetings with ranchers were specifically to discuss concerns regarding potential effects on cattle.

Shell transported the contaminated soil to the landfill prior to testing the soil for its acceptability. This was self-disclosed, however, and once testing was complete, it was determined that the soil did meet Class II landfill criteria.

Shell had an appropriate response to the incident and used all the necessary resources (Hazco, HSE Integrated, WorleyParsons Komex, Acuren, and Jacques Whitford Axys Ltd.).

Shell maintained communication with and provided updates to all parties, including the public and regulatory agencies, throughout the duration of the incident.

Although Shell has significant operating experience with lined pipelines, it had not experienced this particular situation before, nor had ERCB staff.

The ERCB has determined that there were no contraventions of its requirements related to the cause, subsequent response, pipeline repair, and environmental remediation.

3 Actions Taken To Prevent Recurrence

3.1 By Shell Canada Ltd.

Shell developed a five-step Shell Action Plan to further investigate the scenarios that were identified as possible causes of the incident and to develop a plan to ensure the safe start-up and ongoing integrity of the pipeline.

Step 1: Continued Review of Contributing Factors, Conditions, Events—This involves Shell continuing its review of the factors, conditions, and events that contributed to the incident, with the objective of better understanding the role of the various contributing factors in the incident and the extent to which these factors may be unique to the failure location. This is all with a view to further understanding the conditions that might cause corrosion and how those conditions might occur.

Step 2: Model Development—This involves developing a model to help improve Shell's understanding of the failure mechanism and assess the likelihood that similar factors, conditions, and events exist in the remainder of the pipeline and in Shell's other lined pipelines in similar service. The model will initially be developed based on the information

Shell currently has available. That model may be amended to reflect other contributing factors, conditions, and events identified in Step 1 or factors identified in Step 3. The model will assist Shell in developing the integrity plan and start-up plan set out in Steps 4 and 5 respectively.

Step 3: Model Validation—This involves developing and executing, as necessary, sufficient inspections, tests, and other methods to validate the model developed in Step 2.

Step 4: Integrity Plan—To confirm the validity of the model, it will be necessary to complete certain other activities, which may include inspections, tests, sampling, and laboratory testing. It is expected that inspection activities will constitute the majority of activities in this step. Inspections will be completed to ensure that the model can accurately predict if and where corrosion can be expected. Once the model developed in Step 2 is validated, Step 4 of the Shell Action Plan involves developing and executing a plan to ensure the integrity of the pipeline prior to start-up. The plan may involve inspections, hydrotesting, liner integrity verification, cutouts, and repairs.

Step 5: Start-up Plan—This involves developing and executing a plan to restart the pipeline. The plan may include, as necessary, changes to operating envelopes/windows; inspection, mitigation, and monitoring requirements; and operating and maintenance practices.

Steps 1 and 2 have been completed, and Step 3 is nearing completion. Shell is currently working with a third-party inspection company to modify its electromagnetic tools to enable their use in inspecting lined pipelines. Field trials have shown that these tools are capable of inspecting for corrosion of steel carrier pipe through the liner, and inspection work on certain sizes of line pipe in the Shell system has already been completed. This is a new application of the technology and is being developed in response to this incident. Shell is also continuing discussions with suppliers about other inspection methods.

Once the correctly sized inspection tools are available, Steps 4 and 5 can be completed, as described.

With findings gained from its investigation Shell is undertaking a line-by-line assessment of all its lined pipelines, including the shut-in lined pipelines in Waterton. As the assessments of the Waterton pipelines are completed, Shell intends to submit individual plans to the ERCB in support of the restart of each of the pipelines, along with appropriate measures to provide for the long-term integrity of each pipeline.

Shell has committed to share its knowledge relating to the incident with other operators through a variety of industry-based forums, as appropriate, including

- industry association events,
- industry committees (e.g., Canadian Association of Petroleum Producers [CAPP], Canadian Standards Association [CSA]), and
- industry user forums (e.g., Upstream Pipeline Integrity Management Association [UPIMA], Plastics Users Group).

3.2 By the ERCB

The ERCB Operations Group, Pipeline Section, will follow up with Shell on an ongoing basis while Shell continues to develop the necessary inspection tools, test procedures, repair activities, and long-term corrosion control measures for the lined pipelines.

4 ERCB Directed Actions

- That the operation of the failed pipeline and the pipelines Shell voluntarily took out of service (see Appendix A) are suspended until written approval from the ERCB is received allowing the pipelines to be put back into service.
- That Shell develop a plan in order to reduce response time for mobile air monitoring units.
- That Shell develop a plan to ensure that resources dispatched to an incident communicate with the Incident Command Post on arrival.
- That Shell develop a plan to record the names of members of the public, including residents and transients, who arrive at road blocks and are turned away.
- That Shell develop a plan to ensure that reliable data are being collected from the handheld H₂S monitoring units (calibration and bump-test verification). Although air monitoring data gathered by handheld units can have limited use, the timing and location of monitoring, regardless of the accuracy of the results, can provide valuable information.

5 ERCB Follow-up

- The incident investigator will meet with the ERCB Pipeline Section and MPFC to track the progress of the Shell Action Plan, confirmation of existing pipeline integrity, and reinstatement of the subject lined pipelines.
- The incident investigator will follow up with Shell on its commitment to share its knowledge relating to the incident with other operators.
- The incident investigator will follow up with Shell to track its progress on the ERCB Directed Actions.
- The ERCB will distribute a public report directly to all affected parties.

Appendix A Surface Location of HDPE Pipelines in Waterton Area

Pipeline	From LSD	To LSD
Corner Mountain		
WT-24	14-34-4-2W5M	3-3-5-2W5M
WT-24	3-3-5-2W5M	1-3-5-2W5M
North End/Castle River		
WT-63	5-20-6-2W5M	5-20-6-2W5M
WT-60	3-20-6-2W5M	6-17-6-2W5M
WT-61	10-7-6-2W5M	6-17-6-2W5M
CRLBV-5	16-16-6-2W5M	5-20-6-2W5M
CRLBV-4	5-20-6-2W5M	1-20-6-2W5M
CRLBV-3	1-20-6-2W5M	14-16-6-2W5M
CRLBV-2	14-16-6-2W5M	16-16-6-2W5M
WT10-7 well	10-7-6-2W5M	6-17-6-2W5M
Sorge		
WT-CSS	4-4-6-1W5M	4-4-6-1W5M
Smith Canyon		
WT-59	2-8-4-30W4M	16-1-4-1W5M
Carbondale		
WT-65	15-20-6-3W5M	7-20-6-3W5M
CAJCT7-20	7-20-6-3-W5M	16-17-6-3W5M
CALBV-16	16-17-6-3-W5M	12-9-6-3-W5M
CA12-9	12-9-6-3W5M	15-10-6-3W5M
CALBV-13A	15-10-6-3W5M	6-12-6-3W5M
CA 6-12	6-12-6-3W5M	6-12-6-3W5M
CA12-9	12-9-6-3W5M	15-10-6-3W5M
CALBV-13B	15-10-6-3W5M	15-11-6-3W5M
CALBV-12	15-11-6-3W5M	6-12-6-3W5M
CALH6-12	6-12-6-3W5M	1-7-6-2W5M
TX A 3-4	3-4-6-2W5M	4-4-6-2W5M



